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What and How to Kill (Inactivate) SARS-CoV-2?

First published on 12 August 2021 by Boon-How Chew, Nurul Iman Hafizah and Beng-Kah Song for the Pandemic Scientific Response team

Caution: Summary is a preliminary report of work by Pandemic Scientific Response team. It will be continuously updated in accordance to the unfolding of events and emerging of scientific evidence.

In Brief

- Until today, there is no drug that can kill the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), except the convalescent plasma antibody from infected or vaccinated persons.
- Ultraviolet light, irradiation, heat, humidity, light-activated coatings, ozone, disinfectants and house hold detergents have SARS-CoV-2 viricidal property. Note that all data were produced from temperate countries, and higher sunlight intensity, temperature and humidity in tropical countries could display stronger viricidal effects.
- The virus can remain viable and infectious in aerosols for up to **6 hours** and on surfaces up to days and weeks. SARS-CoV-2 is extremely stable at room temperature in pH values 3–10.
- At 37 °C, the stability of SARS-CoV-2 was about **4 hours** on skin and banknotes. Cashless transaction such as eWallet, direct debit or credit card and mobile/Internet banking is safer from infection.
- Virus remains detected at 5 mins with hand soap, become undetected at **15 minutes**. Use of a better hand sanitiser (see below) is necessary.
- Disinfectants that contain ethanol (70%), povidone-iodine (7.5%), chlorhexidine (0.05%), chloroxylenol (0.05%), Benzalkonium chloride (0.1%) or peroxide **inactivate the virus within 5** minutes. Mopping and cleaning the houses, utensils, dishes, cloths and toys with disinfectants such as antiseptic liquid, detergent and bleach are effective.
- 90% of infectious SARS-CoV-2 is inactivated every **7 minutes under sunlight of midday summer** (1.6 W/m2); this duration doubled to about **14 minutes** under a simulated winter sunlight (0.3 W/m2). The dose required to obtain a similar degree of viral inactivation was **twice in dried** samples compared to the wet such as saliva. Outdoor mass sensitisation in tropical countries is unnecessary.
- Higher inactivation of SARS-CoV-2 increases with temperature. The virus was less stable at greater temperature, fairly **unchanged over 14 days at 4 °C** but **undetected within 5 minutes at 70 °C**.
- The half-life of SARS-CoV-2 was strongly dependent on the material, **< 1 hour** on copper, **< 5 hours** on cardboard, **6 hours** stainless steel and **7 hours** on plastic.
- The recovery of SARS-CoV-2 was lower on rough surfaces eg. wood and cloth, and smooth surfaces eg. glass and banknotes; low recovery from porous material eg. paper, and also lower from metallic copper and silver compared to stainless-steel and plastic.
- Personal protective equipment (PPE) eg. PVC face shield, nitrile gloves, Tyvek, the N95 mask, and the N-100 mask harboured infectious virus up to **4–7 days**. Some kind of disinfestations are necessary.
- Self-cleaning textiles is designed by hydrophobizing their surfaces leading to less adhesion of droplets. Biocidal fabrics can be created by coating or impregnating them with copper, silver, or zinc particles.

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Full Summary

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Summary

Severe acute respiratory coronavirus-2 (SARS-CoV-2) is the virus that causes COVID-19. SARS-CoV-2 is transmitted through infected respiratory droplets and aerosols generated by a diseased person when that person sneezes, coughs, speaks, or breathes[1-3]. An individual is infected by the virus through nasal or oral inhalation of the infected droplets or aerosols and then attachment of the virus to the epithelial membrane. For this reason, health officials have advised that individuals should avoid poorly ventilated public places, wear a mask in public places, and increase distance between other individuals.

An important distinction between viruses and micro-organisms such as bacteria is that viruses do not have cellular metabolism and cannot reproduce on their own. For this reason, many do not consider viruses to be alive, and does not refer to killing viruses, but rather to inactivating them. An important consequence is that the virus loses activity over time even when there is no disinfection procedure and the infective titer depended on the types of the material. Therefore, any effort to inactivate the virus must be viewed against the natural decay of the viral population on the same surface, and the titer decayed approximately in exponential with time. Additionally, viral survival in the environment is dependent on multiple factors including temperature, humidity, sunlight, and the matrix in which the virus is suspended within[1]. Studies have shown that SARS-CoV-2 can be inactivated by methods such as ultraviolet (UV) light, atmospheric cold plasma, heat treatment, ozone and light-activated coatings[4].

The possibility of infection via solid surfaces has also been considered. In this scenario, a droplet that contains virus lands on and contaminates an inanimate object. The contaminated object is called a **fomite**. The next person who touches the fomite, could get the virus transferred from the fomite to the person's hand. Infection can occur if the person then touches their nose, mouth, eyes, or ears[5].

Outdoor

The potential for fomite transmission may be significantly reduced in outdoor environments that are exposed to direct sunlight1. The inactivation rate of SARS-CoV-2 in simulated sunlight was approximately 2-fold weaker in culture media than in simulated saliva.

- 90% of infectious viruses are inactivated every **6.8 minutes** in simulated saliva dried on a surface under levels of simulated sunlight representative of summer midday at 40°N latitude (1.6 W/m^2).
- 90% of infectious viruses are inactivated every **14.3 minutes** in simulated saliva dried on a surface under a simulated sunlight of the winter solstice at 40°N latitude (0.3 W/m^2).

Indoor

Under indoor conditions, the half-live of SARS-CoV-2 in aerosols was 1.1 to 1.2 hours (95% credible intervals of 0.64 to 2.64)[2].

A highly controlled experimental model identified monochromatic UV-C (**254 nm**, from a low-pressure mercury lamp) radiation at 3.7, 16.9 and 84.4 mJ/cm^2 illumination exposure time were sufficient to achieve more than 3-log inactivation of 0.05 and 5 MOI at 24 hours; for 1000 MOI required **24 hours of at least 16.9 mJ/cm^2**. To fully inactivate SARS-CoV-2 would require **72 hours of at least 16.9 mJ/cm^2**. The response depends on both the UV-C dose and the virus concentration (dose–response and time-dependent)[6]. The dose required to obtain a similar degree of viral inactivation was twice in dried samples compared to the ones resuspended in simulated saliva.

A multiplicity of infection (MOI) of 0.05 is equivalent to the low-level contamination observed in closed environments (e.g. hospital rooms); MOI 5 corresponds to the average concentration found in the sputum of COVID-19 infected patients; and MOI 1000 is equivalent to a very large concentration corresponding to that observed in terminally diseased COVID-19 patients.

Temperature

The virus was less stable at greater temperature, with the viral titer barely decaying over **14 days at 4 °C**, becoming undetectable after **2 days at body temperature** of 37°C, within **5 min at 70 °C** [3]. In order to inactivate SARS-CoV-2, we may heat virus-containing objects for[7]:

- 3 minutes at temperature above 75°C (160°F).
- 5 minutes for temperatures above 65°C (149°F).
- 20 minutes for temperatures above 60°C (140°F).


Photo by Ketut Subiyanto from Pexels

Humidity

At room temperature (22°C) with a relative humidity of around 65%[3], no infectious virus could be recovered from

- printing and tissue papers after **3 hours.**
- surfaces of wood and cloth on **day 2.**
- glass and banknote on **day 4.**
- stainless steel and plastic **day 7**.

SARS-CoV-1 lasted **3–5 days** before losing 90% of infectivity on dried surfaces.

The virus was less stable on solids at higher humidity. The effect of humidity is a curious result. Higher humidity should hasten evaporation of the droplet and therefore hasten the large change in viral environment that occurs when the virus is dehydrated. We would have expected a higher humidity to preserve the virus; however, this is clearly not observed.

Skin, Banknotes, Cloths and Personal Protective Equipment

A detectable level of infectious virus could still be present on the outer layer of a surgical mask on **day 7** [3,4].

At 4 °C, the virus remains viable on swine skin for **> 14 days**, banknotes **> 4 days**, and for cloths **> 3 days**[4].
At 22 °C, the virus was detected on swine skin, banknotes, and clothing after **24 hours**, **8 hours**, and **4 hours**, respectively[4].
At 37 °C, the stability of SARS-CoV-2 was reduced to **4 hours** for skin and banknotes and **less than 4 hours** for clothing[4].

The viability of SARS-CoV-2 on various porous and nonporous personal protective equipment (PPE) was tested and found that the virus loses its infectivity on PVC face shield, nitrile gloves, Tyvek, the N95 mask, and the N-100 mask after **4–7 days**. While cotton and reinforced nitrile gloves were able to rapidly inactivate the virus, where the infectivity on them diminished after **1 hour and 4 hours**, respectively.

There exist two broad designs of self-cleaning textiles.

1. One is by **hydrophobizing** a surface so that droplets have weak adhesion and roll off at a low tilt angle. This is aided by the fact that many surfaces are worn in near vertical orientation. A hydrophobic coating on nonwoven polypropylene textile had displayed reduced infection compared to hydrophilic textiles that can imbibe droplets of viral suspension.
2. The other approach is to modify the fabric to **incorporate biocidal properties**. Biocidal fabrics can be created by coating or impregnating fabric with a biocide such as copper, silver, or zinc particles.

Detergents and Disinfectants

SARS-CoV-2 is extremely stable in a wide range of pH values at room temperature (pH 3–10), but it is susceptible to standard disinfection methods. Ethanol (70%), detergent, bleach, povidone-iodine (7.5%), chlorhexidine (0.05%), chloroxylenol (0.05%), Benzalkonium chloride (0.1%) or peroxide inactivate the virus within **5 minutes**. Virus remains detected at 5 mins with hand soap, become undetected at **15 minutes** [3].


Photo by Matilda Wormwood from Pexels

Metals: Rough and Smooth/ Flat Surfaces

The virus was inactivated on glass and aluminum after **44 hours** and **4 hours**, respectively[4].

The half-life of SARS-CoV-2 was strongly dependent on the material, **1 hour** for copper, cardboard, stainless steel and **7 hours** on plastic[2].

- On copper, no viable SARS-CoV-2 was measured after **4 hours**.
- On cardboard, no viable SARS-CoV-2 was measured after **24 hours**.
- Viable SARS-CoV-2 was detected up to 72 hours on stainless-steel and plastic surfaces, the reported half-lives were 5.6 and 6.8 hours, respectively, or approximately **18 to 23 hours** for a 90% reduction in infectivity[2].

In another study, silver was shown to have very strong anti–SARS-CoV-2 properties. It was also found that 100% viral reduction with only **1 minute** of virus exposure to either Slicon nitride (Si_3N_4), copper (Cu), and aluminum nitride (AlN)[4].

The surface roughness is another factor in the viability of the virus on surfaces. The etched aluminum sample produced more than 2-log (99%) reduction in **3 hours**, while this duration on control flat aluminum was **48 hours**.

Frequently Asked Questions (FAQ) on Cleaning and Disinfecting

Is the practice of disinfecting individuals through tunnels and chambers recommended to inactivate SARS-CoV-2?
Spraying individuals with disinfectants are not recommended in any circumstances[8]. This is because it would not reduce the sources of viral particles from an infected person, ability to spread the virus through contact and droplets. Besides, the use of large-scale spraying may cause irritation to the eye, nose and skin as well as respiratory complications due to chemical inhalation[9].

Is disinfecting outdoor spaces such as roads and sidewalks recommended to combat the spread of COVID-19 infection?
No, it is not recommended to apply large-scale disinfection in open areas such as roads and sidewalks. This is because the open areas are not considered to be the index of infection. Furthermore, spraying disinfectants in those area would be ineffective because it is inactivated by dirt and debris. In addition, the use of chemical spraying may also endanger human's health related to irritation to the eye, skin or respiratory complications[9].

Is it safe to use sterilizing UV-C lamps for the purpose of disinfection at home?
Although research has suggested that UV-C radiation of 200 – 280 nm is known to inactivate SARS-CoV-2 [7]. However, the UV-C intensity of these lamps are usually of low dose, so it may take longer exposure to a given surface area to potentially provide effective inactivation of a bacteria or virus. Furthermore, the use of sterilizing lamps may also pose health and safety risk depending on the wavelength, dose and duration of the exposure to the radiation. Such risks include eye injury and skin reaction due to direct exposure to UV-C radiation, airway irritation due to ozone inhalation generated by the UV-C lamps and some UV-C lamps may also contain mercury. In the case of using UV-C lamps for disinfection at home, please obtain necessary information particularly related to the health and safety risk as well as the instructions for use[10].

Is hand-held atomizer blue light spray gun effective to inactivate SARS-CoV-2?
The effectiveness of the portable blue light spray gun is still questionable particularly in terms of whether the light emitted is in the form of UV-C radiation, or even so, whether the radiation dose is sufficient to inactivate the virus[10]. Additionally, the right disinfectants must be used in the container of the sprays. The practice of spraying disinfectants should be done carefully to avoid further health complications such as irritation to the eye and skin as well as respiratory problems[9].

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